PB80-217698

Independent Coastdown Road Load Power Determination for Ten Diverse Production Vehicles

(U.S.) Environmental Protection Agency
Ann Arbor, MI

Aug 80

U.S. Department of Commerce
National Technical Information Service
NTIS

EPA-AA-SDSB-80-15

PB80-217698

Technical Report

"Independent Coastdown Road Load Power Determination for Ten Diverse Production Vehicles"

by

Terry Newell

August 1980

NOTICE

Technical Reports do not necessarily represent final EPA decisions or positions. They are intended to present technical analysis of issues using data which are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments which may form the basis for a final EPA decision, position or regulatory action.

Standards Development and Support Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Office of Air, Noise and Radiation
U.S. Environmental Protection Agency

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-AA-SDSB-80-15	2.	3. RECIPIENT'S ACCESSION NO. PB80 217698
4. TITLE AND SUBTITLE Independent Coastdown Road Load Power Determination for Ten Diverse Production Vehicles		5. REPORT DATE August 1980 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Terry Newell		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency Office of Mobile Source Air Pollution Control Standards Development and Support Branch Ann Arbor, MI 48105		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Same as box 9		13. TYPE OF REPORT AND PERIOD COVERED Technical 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

As part of the continuing effort by the U.S. Environmental Protection AGency to verify the integrity and accuracy of alternative determinations of dynamometer power absorber (PAU) settings, a test program involving ten various production vehicles was conducted. The objective of this program was to determine the appropriateness of the dynamometer PAU settings, submitted to EPA by the vehicle manufacturers as part of the 1979 model year certification process, for production vehicles.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Tests Automobiles Dynamometers Motor Vehicles	Certification	

18. DISTRIBUTION STATEMENT RELEASE UNLIMITED	19. SECURITY CLASS *(This Report)* UNCLASSIFIED	21. NO. OF PAGES
	20. SECURITY CLASS *(This page)* UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (9-73)

I. Introduction

As part of the continuing effort by EPA to verify the integrity and accuracy of alternative determinations of dynamometer power absorber (PAU) settings, a test program involving ten various production vehicles was conducted. The objective of this program was to determine the appropriateness of the dynamometer PAU settings, submitted to EPA by the vehicle manufacturers as part of the 1979 model year certification process, for production vehicles.

II. Discussion

Ten production vehicles were selected for testing in this program. The three major domestic manufacturers were represented in the set of test vehicles, which consisted of six General Motors products and two vehicles each manufactured by the Ford Motor Company and the Chrysler Corporation. The inertia weight classes of the test vehicles ranged from 2000 to 4500 pounds. More detailed descriptions of these ten vehicles appear in Table 1.

There were two important criteria by which the vehicles to be tested were chosen. The foremost consideration was the use of dynamometer PAU settings in the 1979 model year (MY1979) certification process that were lower than the range of values typically submitted for other similar vehicles. Secondarily, selection was based on the sales volume of the vehicles chosen. While there may have been other vehicles for which manufacturers submitted apparently low PAU settings, the relatively high sales volume of the ten vehicles chosen increased the potential impact on fleet-wide emissions and fuel economy of any dynamometer underloading during the certification process.

In selecting the specific production vehicles to represent each of the ten models chosen, care was taken to avoid vehicles that had been altered in any way that could have led to unrepresentative coastdown times. Internal alterations avoided in selection included any modifications to the engine, drivetrain, or braking system. Unacceptable external alterations included the addition of roof racks, air dams, or non-standard mirrors. All tires used in the coastdowns were either original equipment or directly comparable to the originals. The vehicles were all checked for correct wheel alignment before testing. These precautions should have eliminated any effects of unrepresentative frictional drag, aerodynamic drag, or inertial effects.

This testing program was conducted by Automotive Testing Laboratories (ATL) as a task order under a contract with EPA.1/ The coastdowns were performed on the track at the Transportation Research Center of Ohio (TRC) in East Liberty, Ohio. Test vehicles were procured by ATL from local sources, such as private owners and area car rental agencies. All vehicles and tires used in the program were required to have accumulated a minimum of 100 km (62 mi) before testing commenced. This requirement was exceeded by a considerable margin for all of the test vehicles.

A value for road load horsepower was determined for each vehicle in accordance with the EPA Recommended Practice for Determination of Vehi-

cle Road Load.2/ In this method of determining road load the vehicle is accelerated to a speed greater than 60 mph, the transmission is shifted to neutral, and the vehicle is allowed to freely decelerate (coastdown) until the speed has dropped to less than 20 mph. Vehicle speed-versus-time data is collected during each of a minimum of five pairs of alternating-direction coastdowns. This road coastdown data is subjected to analysis by a computer program; the program output includes values of the acceleration coefficients a_0 and a_2, corrected to the standard ambient air temperature of 68°F (20°C) and barometric pressure of 29.00 in Hg. From this road acceleration data, the force acting on the vehicle at 50 mph, or any other velocity within the range spanned by the coastdown, can be computed. A "target" 55-45 mph coastdown time is then calculated for reproducing this force on the dynamometer at the test inertia weight. The correct dynamometer PAU setting is determined when the 55-45 mph coastdown time on the dynamometer matches the ambient- and mass-corrected 55-45 mph "target" coastdown time. This matching reproduces, for operation on the dynamometer, the 50 mph force experienced by the vehicle on the road.

The results of the independent determination of dynamometer PAU settings for the test vehicles are listed in Table 2, under the heading "ATL Value." The values submitted by the manufacturers are shown in the table under the heading "Mfr. Value."

As can be seen in Table 2, the dynamometer PAU settings submitted by the manufacturers are generally lower than those independently determined by ATL. The sole exception among these ten vehicles was the Dodge Omni, for which the two values were equal.

A significant difference was observed between the dynamometer PAU settings supplied by the manufacturers for certification, and those independently determined by ATL. For this reason, the total force acting on the test vehicles at the match-point speed of 50 mph was examined. The existance of a force offset would indicate differences between test and production vehicles, while an offset only between the dynamometer PAU settings would provide evidence for differences in the tires used, the degree of tire wear, in tire behavior on the track and the dynamometer, or in dynamometer calibration between the dynamometers of the manufacturers and ATL.

The total road force on the test vehicles, operating on the track or on the dynamometer at 50 mph, can be computed using Newton's Second Law and the coastdown data. Computer analysis of the coastdowns results in the derivation of ambient-corrected, vehicle-specific 55-45 mph coastdown times. The force is then computed, using the equation:

$$F = ma = m\left(\frac{\Delta v}{\Delta t}\right)$$

Where:

F = total force at velocity of 50 mph.

m = inertial weight + driving rotating equivalent.

Δv = change in velocity (10 mph) during 55-45 coastdown.

Δt = time (seconds) required for 55-45 mph coastdown.

$\frac{\Delta v}{\Delta t}$ = approximation of acceleration at 50 mph.

Results of the computations of total force at 50 mph appear in Table 3. The force calculated for the production vehicle is in the column headed "ATL Force," and the force calculated for the certification vehicle is shown under "Mfr. Force." The 55-45 mph coastdown times are also listed in this table. These times are the "target" coastdown times, intended to reproduce the total 50 mph road force experienced by the vehicle on the dynamometer at the test inertia weight, as calculated by the manufacturers and by ATL.

III. Results

The manufacturer-submitted dynamometer PAU settings were found to be lower than those independently determined in this test program, with the exception of the Dodge Omni, for which the two values were equal. The percentage difference, defined as $\frac{\text{ATL HP - MFR HP}}{\text{MFR HP}} \times 100$, ranged from zero (for the Omni) up to 36 percent (for the Monza). The mean difference was 12.3 percent.

The Corvette and the Monza dynamometer PAU settings submitted by General Motors were derived by determining the reference frontal areas of these vehicles, and using the equation in 40 CFR 86.129-79. The other eight vehicles had the manufacturer-submitted PAU settings determined by the coastdown method, which was used by ATL for all ten vehicles. Thus, the manufacturer PAU settings for the Monza and Corvette are not directly comparable to the ATL-determined values.

When these two vehicles are deleted from the computation of percentage difference in Table 2, both the mean and the range are decreased. The mean difference drops from 12.3 to 8.7 percent, while the range is narrowed to zero-to-24.8 percent.

Since the Monza and Corvette used the frontal area method to determine PAU settings, no target dynamometer coastdown times were calculated for these vehicles. Since this target time, Δt, is necessary for these computations of the total road force acting on the vehicle at 50 mph, there are no entries in several of the columns of Table 3 for these two vehicles.

Calculation of the force on the test vehicles at 50 mph shows that the forces averaged nearly the same for both the production and the prototype certification vehicles. The percentage difference, defined as $\frac{\text{ATL FORCE - MFR FORCE}}{\text{MFR FORCE}} \times 100$, ranged between -7.1 percent and +30.3 percent. The mean difference in total 50 mph force was +2.8 percent.

Figure 1 presents a plot of percentage difference in dynamometer PAU settings (vertical axis) against the percentage difference in total

force at 50 mph (horizontal axis). These are eight data points on the graph, representing each vehicle except the Chevrolet Corvette and Monza.

The dashed line in Figure 1 represents the situation of the percentage difference in dynamometer PAU settings being equal to the percentage difference in total force at 50 mph. If a systematic difference exists between the test vehicles used in determining PAU settings as part of the MY 1979 certification process, and the production vehicles that were used in this program, then the data points would be expected to cluster near this dashed line. Since the data points do not cluster in any linear fashion, it can be concluded that the discrepancies in the PAU settings are not attributable to any systematic differences between the certification and production vehicles. Possible reasons for the observed discrepancies include (i) differences in the degree of wear of the tires used for, or in tire behavior during, coastdowns conducted by the manufacturers and by ATL, or (ii) calibration differences between dynamometers of ATL and the manufacturers.

The results for three of the test vehicles appear anomalous, relative to the test fleet as a whole. As indicated earlier, the dynamometer PAU settings submitted by the manufacturer for the Corvette and the Monza were determined using the frontal area equation. These vehicles represent two of the three greatest percentage differences observed in PAU settings. The third case is the Granada, which was unique among vehicles tested in that it is represented in Figure 1 as the only point that is both near to the dashed line and significantly displaced from the origin.

The following is a brief discussion of several possible reasons for the apparently anomalous results for the aforementioned vehicles.

(a) Erroneous test program data. It is possible that errors occurred during the test program in either the collection or transcription of vehicle and coastdown data. For example, the weight of a vehicle is an important parameter in computing the force acting on that vehicle. The test weight of 3,660 lb (1,660 kg) reported by ATL for the Monza appears to be excessive for this vehicle. By comparison, World Cars 1979 3/ lists the same Monza (2 + 2 Coupé, 196 CID 6-cylinder engine) as weighing 2,775 lb (1,259 kg), and the inertia weight class used for certification (based on curb weight plus 300 lb) was only 3,500 lb (1,588 kg).

(b) Advantageous use of options in road load power determination. This refers particularly to the use of the frontal area equation for determination of the PAU settings for the Monza and the Corvette. Since EPA approval of the coastdown method of road load power determination, the majority of domestically produced vehicles have been certified with PAU settings determined in this way. It is safe to assume that the manufacturers will submit PAU settings for a particular vehicle determined by the method that results in the lowest value for the PAU setting. Particularly the Corvette, with its unusual body geometry, may benefit considerably from use of the frontal area equation.

(c) Anomalous vehicles. Despite the precautions exercised in selection of the ten production vehicles tested, the possibility exists that a vehicle unrepresentative of its model line was used in the program. This possibility seems most likely in the case of the Granada, for which the ATL target coastdown time and calculated total force at 50 mph appear to be inconsistent with the vehicle's general body shape and weight class. Alternately, the prototype Granada used in certification may have been unrepresentative of the production vehicles. In any case, there are wide discrepancies in the data on the Granada.

Three of the ten test vehicles, the Corvette, Granada, and Monza, exhibited the largest discrepancies in dynamometer PAU settings. As previously noted, no comparison of the values for the total road force at 50 mph were made for the Monza and the Corvette. The Granada also exhibited the greatest discrepancy between total road forces at 50 mph as calculated from the manufacturers and ATL data. Since these three vehicles appear anomalous in one fashion or another, it is useful to consider the remaining set of seven vehicles.

The dynamometer PAU settings for those seven vehicles differed by a mean of only 6.4 percent. The range of the percentage difference is then zero to 13.6 percent. This mean percentage difference is barely half that of the entire ten vehicle test fleet.

The calculated total road force for the seven vehicles differs by a mean of -1.1 percent, with the range being -7.1 to +6.3 percent. The scattering of the force percentage difference for these seven vehicles, and the much lower mean difference in PAU settings suggests that overall these models were certified experiencing total force that was representative of their respective production vehicles.

The results from this test program give some indication of an effect based on odometer mileage. Of the ten vehicles tested, four had more than 10,000 miles on the odometer, five had between 4,000 and 10,000, and the odometer mileage was not recorded for one vehicle. Comparing the rightmost columns of Tables 1 and 3 reveals some correlation between vehicle odometer mileage and percentage difference in total 50 mph force, where greater mileage is associated with lower, generally negative, percentage differences. For all vehicles with less than 10,000 odometer miles, total force calculated from the ATL coastdown data was greater than that calculated from manufacturer supplied data. The reverse was true of vehicles with greater than 10,000 odometer miles. A least-squares regression of percentage difference in road force against odometer mileage yielded a value of -0.71 for the correlation coefficient, and an r-squared value of 0.50. Thus 50 percent of the variation in the percentage difference in total force can be attributed to variation in odometer mileage, with increases in odometer mileage associated with decreases in road force.

This odometer mileage related offset has been observed previously in relation to fuel economy. Several studies have shown that the fuel economy of in-service vehicles is generally below that of EPA certification vehicles when odometer mileage is low, and that this offset is gradually reduced and in some cases reversed with increased odometer

mileage.4/ A reduction in the total (50 mph) force experienced by vehicles as odometer mileage increases, as observed in this program, is consonant with the more well-known increase in fuel economy.

This information indicates that a consistent offset in both dynamometer PAU setting and calculated road force might have been observed in this program if all the production vehicles selected had low accumulated mileage, since the road force offset appears to diminish with accumulated mileage. It may be advisable to set an upper bound on the accumulated mileage of all road load determination vehicles in the future.

IV. Conclusions

1. Most of the vehicles (7 out of 10) appear to have experienced total force at 50 mph on the certification dynamometers that was representative of the road force experienced by the corresponding production vehicles.

2. Since total force was representative of production vehicles, the discrepancies in dynamometer PAU settings were likely the result of differences in vehicle tire behavior, and/or slight calibration differences between the dynamometers at ATL and the manufacturers' facilities; no data acquired in this test program indicated consistent differences between certification and production vehicles.

3. For the two vehicles in this program (Corvette, Monza) that had frontal area determined dynamometer PAU settings submitted to EPA by the manufacturer, those values were considerably lower than values independently determined by the coastdown method. The test weight of the Monza reported by ATL appears to be quite high, which may have caused the discrepancy for that vehicle; while the Corvette, which has an unusual body configuration, may benefit more than many other vehicles through the use of the frontal area equation.

4. The PAU setting and calculated road force for the Granada, as determined by ATL in this program, seem to be anomalous when compared to the data on the entire test fleet. It would appear that the specific Granada used in the program may have been an atypical vehicle. Conversely, it may have been that the Granada prototype used in certification was unrepresentative of the production vehicles.

V. Recommendations

While results of this program indicated that the road forces calculated from data submitted by the manufacturers are generally appropriate for and representative of production vehicles, three recommendations should be considered.

1. In future test programs of this type, concerned with comparing road-versus-dynamometer vehicle performance, at least one contractor-to-EPA correlation vehicle should be included. This would resolve the question of possible dynamometer differences.

2. When in similar test programs a vehicle appears to yield anomalous results, the cause of such behavior should be determined,

and additional vehicles tested if necessary.

3. Due to the possibility of decreased total 50 mph force resulting from increases in odometer mileage, it may be desirable to set an upper bound on the mileage of road load determination vehicles. A mileage bound consistent with certification vehicle requirements would be approximately 4,000 miles, with some acceptable tolerance in excess of that figure.

References

1/ Task Order No. 5 for Contract No. 68-03-2693, "Coastdown Road Load Power Determination of Ten Diverse Production Vehicles," March 1, 1979.

2/ "EPA Recommended Practice for Determination of Vehicle Road Load," Attachment I to OMSAPC Advisory Circular No. 55A, February 8, 1978.

3/ World Cars 1979, edited by the Automobile Club of Italy, Herald Books, Pelham, NY, 1979, p. 268-269.

4/ Murrell, Dillard, "Passenger Car Fuel Economy: EPA and Road," Draft of Report to the Congress, April 1980, p. 66-68.

Table 1

Ten Diverse Production Vehicles

Mfr.	Make & Model	Inertia Wgt.	Engine CID (L)	A/C	Odom.
Ford	Ford Fiesta	2000 lb.	98 (1.6)	Yes	12412
Chrysler	Dodge Omni	2500 lb.	105 (1.7)	No	10873
GMC	Chevrolet Monza	3500 lb.	196 (3.2)	Yes	8651
Ford	Ford Granada	3500 lb.	250 (4.1)	Yes	N/A
GMC	Pontiac Firebird	4000 lb.	301 (4.9)	Yes	12417
Chrysler	Chrysler Lebaron	4000 lb.	318 (5.2)	Yes	8716
GMC	Chevrolet Corvette	4000 lb.	350 (5.7)	Yes	4478
GMC	Cadillac Eldorado	4000 lb.	350 (5.7)	Yes	8220
GMC	Pontiac TransAm	4000 lb.	402 (6.6)	Yes	18449
GMC	Oldsmobile '98'	4500 lb.	402 (6.6)	Yes	8443

Table 2

Dynamometer Power Absorber (PAU) Settings, in HP

Vehicle	Mfr. Value	ATL Value	% diff.
Fiesta	7.3	8.05	10.3
Omni	7.8	7.8	0.
Monza	8.3 (1)	11.3	36.1
Granada	10.1	12.6	24.8
Firebird	8.8	10.0	13.6
Lebaron	10.8	11.6	7.4
Corvette	8.0 (1)	9.4	17.5
Eldorado	9.6	10.0	4.2
TransAm	9.5	9.9	4.2
Olds '98'	11.6	12.2	5.2
		mean % difference =	12.3

(1) Manufacturer submitted PAU setting as derived from vehicle frontal area and Federal Register equation.

Table 3

Total Force at 50 mph, in Newtons

	Manufacturer		ATL		
Vehicle	55-45 Δt	Force	55-45 Δt	Force	% diff.
Fiesta	10.12 s	408.4	10.32 s	400.6	- 1.9
Omni	12.22 s	422.1	13.16 s	392.1	- 7.1
Monza (1)	-	-	13.61 s	531.2	-
Granada	15.84 s	456.2	12.16 s	594.3	+30.3
Firebird	16.63 s	496.7	17.30 s	477.3	- 3.9
Lebaron	15.21 s	543.1	14.66 s	563.5	+ 3.8
Corvette (1)	-	-	14.24 s	579.5	-
Eldorado	15.14 s	545.4	14.25 s	579.7	+ 6.3
TransAm	16.16 s	510.9	17.17 s	481.0	- 5.9
Olds '98'	15.46 s	601.0	15.35 s	605.4	+ 0.7
		mean percent difference =			+ 2.8

(1) Manufacturer submitted PAU setting determined using frontal area. No dynamometer target coastdown times calculated.

Figure 1

Percent Difference in 50 mph Force (from Table 3) plotted against Percent Difference in Dynamometer PAU Settings (from Table 2)